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CHARACTERISTICS OF EFFLUENTS FROM SEPARATE SEPTIC TANKS TREATING GREY & BLACK WATERS FROM THE SAME HOUSE

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Ontario
Ministry of the Environment

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CHARACTERISTICS OF EFFLUENTS

FROM

SEPARATE SEPTIC TANKS TREATING GREY WATER

AND

BLACK WATER FROM THE SAME HOUSE

By

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PREFACE

In Ontario approximately 550,000 septic tank-leaching bed systems are in continuous use for household sewage disposal in rural areas. An additional 160,000 are used to service summer cottages.

There is an increasing tendency, particularly in cottage development, to use facilities other than a septic tank for treatment of toilet wastes and thus the characterization of other water-borne wastes has become necessary.

This report presents data on the characteristics of waste streams as obtained at a residence from which the toilet and grey water discharges have been separated.

M.B. Fielding, P.Eng.

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CHARACTERISTICS OF EFFLUENTS FROM SEPARATE SEPTIC TANKS TREATING GREY WATER AND BLACK WATER FROM THE SAME HOUSE.

SUMMARY

The use of mechanical, chemical or incineration package units for treatment of toilet wastewater from individual houses puts forward the necessity of separate treatment of grey water from kitchen, bathroom, and laundry.

The chemical and bacteriological characteristics of septic tank effluents from two separate septic tanks used by one house for grey water and black (toilet) wastewater treatment were studied for a period of nine months. Phosphorus free detergents were used in the house.

The concentrations of the total phosphorus and total Kjeldahl nitrogen in the grey water septic tank effluent were 1.4 and 11.3 mg/l respectively i.e. about 10 times lower than in the effluent from the toilet wastewater septic tank. However, the average concentrations of the total and fecal coliform organisms in the grey water septic tank were higher than in the effluent from the toilet septic tank. They were 24×10^6 and 1.4×10^6 per 100 ml respectively.

The effect of soil filters on removal of chemical and bacteriological contaminants from the septic tank effluents is discussed.

The determined accumulation rates of sludge were about 8.3 litres per person per year in the grey water septic tank and about 65.7 litres per person per year in the black (toilet) water septic tank. The calculated time intervals between grey water septic tank cleanings were about 8 to 10 times longer than the respective time intervals recommended for normal household septic tanks.

CHARACTERISTICS OF EFFLUENTS FROM SEPARATE SEPTIC TANKS TREATING GREY WATER AND BLACK WATER FROM THE SAME HOUSE

1. INTRODUCTION

The most common subsurface disposal system, for treatment of household wastewater, consists of a septic tank for primary wastewater treatment and of a leaching bed for disposal and additional treatment of the septic tank effluent. The household wastewater discharged into the septic tank contains, usually, the toilet wastes or the so called "black water" mixed with the "grey water" which includes the discharge from the kitchen sink, tub and shower, bathroom lavatory, dishwasher, and clothing washing machine.

The quality of the septic tank effluent depends, mostly, on the duration of the biological and chemical treatment of the wastewater in the tank or on the so called detention time (in days) which represents the ratio between the volume of the septic tank and the volume of the daily wastewater discharged from the house. The quality of the effluent depends also on the contents of organic matter in the wastewater. The presence of large amounts of organic matter which has undergone little breakdown (e.g. from the kitchen) may contribute to higher bacterial growth in the tank.

Without increasing the volume of the septic tank, the efficiency of the domestic black (toilet) wastewater treatment can be improved by lengthening the detention time through discharging the grey water to a separate disposal system. Separate treatment of domestic grey water becomes more significant in connection with the increasing number of different mechanical, chemical, thermal, etc. single home package units for domestic wastewater treatment which appeared on the market in recent

years. The loading of such units with great amounts of wastewater from laundry, bathroom or kitchen seems to be uneconomical and the use of separate subsurface disposal systems for grey water treatment becomes highly desirable.

Available publications provide information on quantities of wastewater discharged from separate house fixtures[1-4], however, data on chemical and bacteriological characteristics of grey water are imperfect. The qualitative data relate often to grey water made up artificially[5], or to grey water intercepted immediately after dishwashing, bathing, and hand and face washing[6-8]. Sufficient data characterizing the effluent from a septic tank, where the grey water was detained and digested for some days, are not available though, as known, the detention time affects the effluent quality. The septic tank effluent is the primary treatment product carrying the contaminants into the soil and ground water or even directly to the surface water and thus, information on the effluent quality is of utmost importance.

The intention of this project was to study the chemical and bacteriological characteristics of an effluent from a septic tank where grey water is treated and to compare the quality of the effluent with that of an effluent from another septic tank at the same house used only for black (toilet) wastewater treatment.

It was also the intention of this study to evaluate the ability of leaching beds or sand filters to remove nutrients and coliform organisms from effluent of grey water septic tank. The accumulation rates of the sludge in both of the septic tanks and the sludge characteristics were also studied.

2. MATERIALS AND METHODS

A three resident, single-family household, located in Hawkestone Ontario, was selected for this study. Two separate sewage disposal systems were used for the household sewage disposal. One system made up of a two-compartment concrete septic tank with a liquid volume of 3410 litres and of a leaching bed with 135 metres of distribution pipes was used exclusively for the toilet (black) wastewater treatment. The other disposal system made up of a one-compartment, cylindrical, steel septic tank with a liquid volume of 1130 litres and of a leaching bed with 50 metres distribution pipes was used for treatment of the grey water from the kitchen sink and from the tub and shower in the bathroom. Phosphorus free detergents were used in the house for washing dishes (by hand) and for cleaning the tub and sinks. The wastewater from the clothing washing machine was not discharged to either of the above tanks. The arrangement of the two household disposal system is shown in Figure 1.

Both of the septic tanks were connected to the house by short tight pipes, so that no other water but wastewater from the house could enter the tanks. Septic tank effluent samples from the concrete tank were taken from the header connecting the concrete tank and the leaching ' 'es from the steel tank were taken through a hole in the sept · oump. The samples in both cases were taken ·el of the liquid. The sampling point

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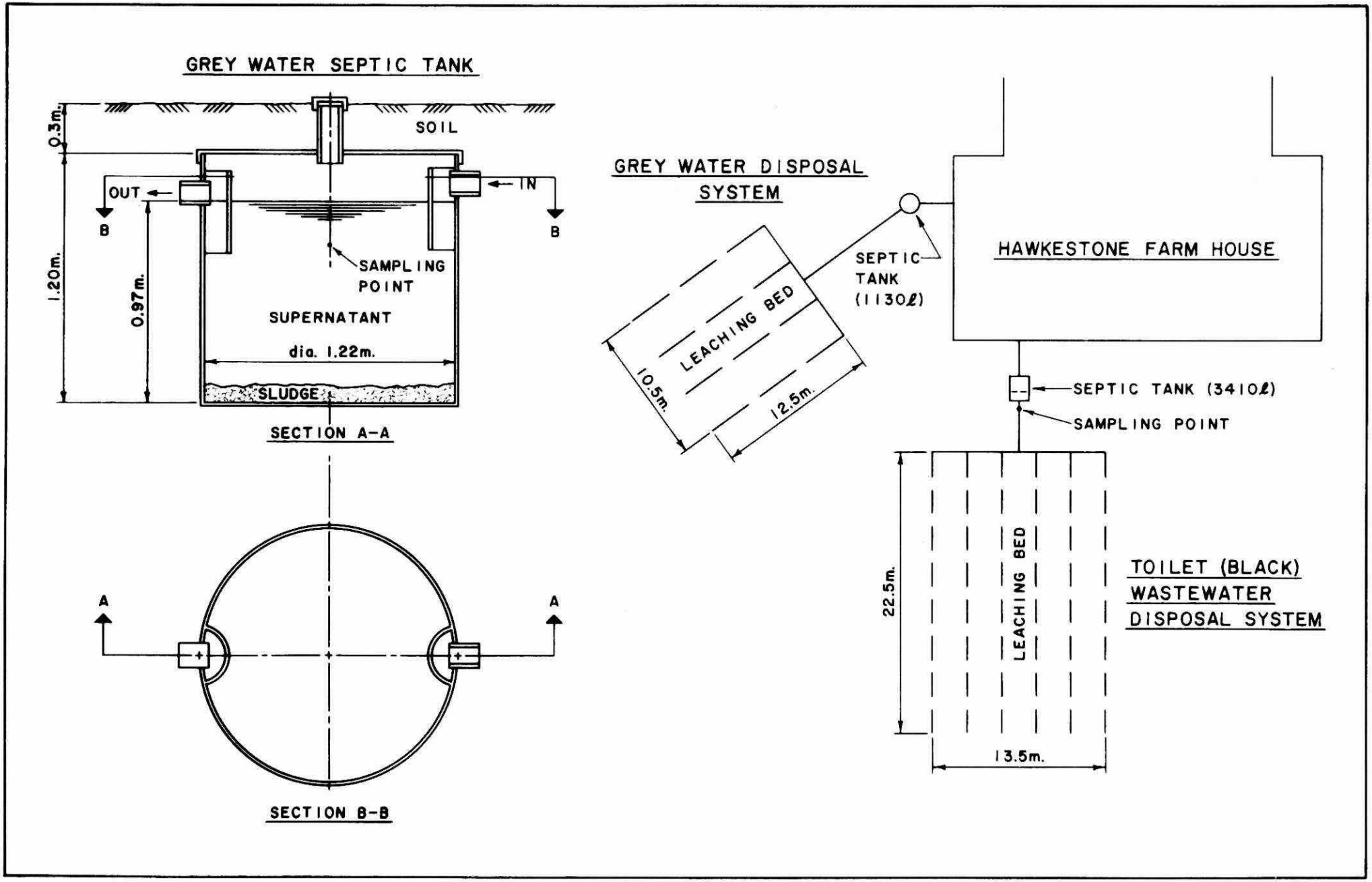

FIGURE 1 - HOUSEHOLD WASTEWATER DISPOSAL SYSTEMS

bacteriological contaminants.

By using a transparent cylindrical sludge sampler described elsewhere[9] the depth of the sludge in the septic tanks under study was measured and the sludge accumulation rate calculated.

The amount of water discharged from the toilet tanks was measured by using counters attached to the toilet flushing mechanism. An average of 118.0 litres of water per person per day (1/p/d) were flushed into the concrete septic tank with the toilet waste. The detention time of the sewage in that tank was about 10 days.

The amount of water discharged from the kitchen sink, and bathroom into the cylindrical steel septic tank was not measured and the estimation of water use was based on literature data[7,3,4]. The reported relations between the amounts of water discharged from the kitchen and bathroom jointly to the amount of water discharged from the toilet were 0.72 by Laak[7], 1.20 by Bennett and Linstedt[3] and 1.62 by Siegrist et al[4] (Table 1). The weighted average 1.07 was used in this study and thus the estimated discharge of water from the kitchen and bathroom was about 126 1/p/d. The detention time of the grey water in the tank is assumed to be about three days.

TABLE 1

HOUSEHOLD WATER USAGE (literature data)

USAGE	Laak[7]		Bennett et al[3]		Siegrist et al[4]		Average	
	l/p/d	%	l/p/d	%	l/p/d	%	l/p/d	%
Toilet	74.9	47.8	56.8	33.4	34.8	21.6	55.5	34.1
Kitchen	13.6	8.7	26.5	15.6	18.6	11.5	19.6	12.0
Bathroom	40.1	25.6	41.6	24.4	37.9	23.5	39.9	24.5
Laundry	28.0	17.9	45.4	26.7	39.8	24.7	37.7	23.2
Misc.	-	-	-	-	30.3	18.8	10.1	6.2
Total	156.6	100	170.3	100	161.4	100	162.8	100
Kitchen and Bathroom Usage/Toilet Usage	0.72		1.20		1.62		1.07	

1 litre = 0.22 Imp. gallons = 0.26 U.S. gallons

3. RESULTS AND DISCUSSION

3.1 Accumulation Rate of Sludge in the Grey and Black Water Septic Tanks

The grey water septic tank, at the farm house, was pumped out on June 2, 1976 after about 1300 days of operation. Before pumping out the tank, the depth of the sludge and of the total liquid in the tank was measured. It appeared that the depth of the sludge accumulated in the tank during the 3.6 year period, between the septic tank cleanings, was only 7.6 cm and the total amount of sludge accumulated was 89 litres. The calculated accumulation rate was 0.023 litres per person per day (1/p/d) or about 8.3 litres per person per year (1/p/y). The observed sludge accumulation rate was much lower than the rates usually observed in normal septic tanks used for domestic wastewater treatment which are up to 69 1/p/y in the USA[10] and up to 80 1/p/y in Ontario, Canada[11].

Assuming the permissible highest level of the sludge in the grey water septic tank before pumping out the tank is 0.46 m below the outlet fitting* it will take about 24 years until the sludge reaches the maximum permissible level in the tank, at which time cleaning of the tank will be required.

The observed low accumulation rate of the sludge in the grey water septic tank is of practical importance because such a septic tank would require pumping out only once in about 20 years.

The sludge accumulation rate in the concrete septic tank used

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* According to the Ontario Septic Tank recommendations[12], the permissible highest level of sludge in normal septic tanks, used for domestic wastewater treatment, is 0.46 m below the bottom of the outlet fitting.

for black (toilet) wastewater treatment was about 0.18 l/p/d i.e. about eight times higher than in the grey water septic tank. The calculated permissible time between cleanings of the toilet septic tank is about eight years. It is, however, worthwhile to note that the toilet (concrete) septic tank was about 50% bigger than normal septic tanks required by regulations[12].

3.2 Characteristics of Effluents From Grey Water and Black (Toilet) Wastewater Septic Tanks

a. Phosphorus Concentration and Removal of Phosphorus by Soil

Phosphorus is a key element contributing to eutrophication of surface water and it should be removed from wastewater. It seems obvious that the amount of phosphorus compounds in the food consumed by the residents and, consequently, in the excreta discharged into the toilet septic tank must considerably exceed the amount of phosphorus in the grey water when non phosphorus detergents are used by the household.

Table 2 demonstrates the mean concentrations of contaminants in the effluents from the two septic tanks where grey water and black water are treated. The numbers of weekly samples tested and the range of contaminant concentrations are also shown. Table 2 also shows concentrations of some contaminants in the house tap water as well as concentrations of contaminants in grey water from the kitchen and bathroom of houses using detergents containing phosphorus as reported by Olsson et al[6].

The average concentrations of the total phosphorus in the effluents from the grey and black water septic tanks of this study were 1.4 and 18.6 mg/l (as P) respectively. The respective concentrations of the soluble phosphorus were 0.17 and 15.2 mg/l (Table 2).

TABLE 2 CONCENTRATIONS OF CONTAMINANTS IN EFFLUENTS FROM GREY WATER AND BLACK (TOILET) WATER SEPTIC TANKS *

	GREY WATER TANK**			BLACK WATER TANK			HOUSE TAP	GREY WATER**
	N.S.	Range	Mean	N.S.	Range	Mean	Water	Ref. (6)
Total Phosphorus (as P)	19	0.8 - 3.2	1.4	24	16 - 22	18.6	0.04	7.8
Soluble Phosphorus (as P)	19	0.02 - 0.26	0.17	24	3.5 - 21	15.2	<0.02	0.24
Total Solids	19	284 - 854	528	25	521 - 745	621	-	518
Suspended Solids	19	25 - 510	162	24	37 - 261	77	-	141
BOD_5	18	35 - 245	149	25	38 - 160	90	-	196
TOC	17	30 - 375	125	22	68 - 160	97	-	-
COD	18	119 - 870	366	23	175 - 490	258	-	-
pH	19	6.5 - 7.3	6.8	25	7.2 - 8.5	7.8	8.2	-
Ammonia (as N)	19	0.1 - 8.1	1.7	24	120 - 160	138	<0.1	-
Total Kjeldahl Nitrogen (as N)	19	5.5 - 18.0	11.3	24	140 - 170	153	-	6.5
Nitrite (as N)	18	0.01 - 0.24	0.04	25	0.01 - 0.02	0.02	-	0.01
Nitrate (as N)	18	<0.1 - 0.2	0.12	25	0.1 - 0.3	0.22	-	-
Chlorides (as Cl)	18	20 - 88	48	21	86 - 128	98	2	30.3
Sulfates (as SO_4)	19	4 - 19	11	24	23 - 48	40	13	-
Aluminum (Al)	15	< 0.02 - 0.27	0.12	16	0.05 - 0.28	0.14	-	-
Iron (as Fe)	17	11 - 28	17.5	24	0.26 - 3.0	1.2	0.1	-
Calcium (as Ca)	19	4 - 18	9	23	13 - 38	29	14	26.6
Magnesium (as Mg)	18	1 - 6	4	21	1 - 9	4	1	5.5
Sodium (as Na)	18	59 - 90	76	25	96 - 110	101	-	50.4
Potassium (as K)	19	4.5 - 13.0	8.9	25	26 - 46	41	-	7.1
Hardness (as $CaCO_3$)	16	26 - 54	39	23	65 - 108	87	39	-
Alkalinity (as $CaCO_3$)	18	125 - 169	148	23	580 - 775	669	103	-
El. Conductivity (µmho/cm)	18	330 - 510	443	25	1440 - 1900	1724	225	-
Total Coliform Org./100 ml.	18	$(0.06 - 134) \times 10^6$	24×10^6	25	$(0.003-0.9) \times 10^6$	0.25×10^6	0	3.6×10^6
Fecal Coliform Org./100 ml.	18	$(0.005-21.0) \times 10^6$	1.4×10^6	23	$(0.002-0.17) \times 10^6$	0.04×10^6	0	0.88×10^6

* All values in mg/l except of coliform organisms, pH and el. conductivity.

** The grey water consists of kitchen and bathroom wastewaters.

N.S. - number of samples

As it follows from the water usage and from the phosphorus concentrations in the septic tank effluents the output of phosphorus from the grey water septic tank was 176.4 mg/p/d and from the black water septic tank 2194.8 mg/p/d. The total annual phosphorus discharge from the septic tanks was about 865 grams per person. According to Vollenweider[13] the mean annual phosphorus loading from treated and untreated domestic sewage is about 800 grams per person. About 88% of the phosphorus in the grey water was in a nonsoluble form while 82% of the phosphorus in the effluent from the toilet septic tank was in a soluble form (Table 2).

The observed low concentration of phosphorus in the grey water septic tank effluent is of importance when considering the area required for a leaching bed or sand filter for grey water disposal, or when considering the minimum permissible distance of the system from lakes or rivers. As shown by Brandes[14] the phosphorus retention ability of subsurface sewage disposal systems may be higher than 67%, even when the filtering soil contains up to 83% of sand. Most of the phosphorus was fixed in the soil below the leaching bed area. Another study has shown[15] that a one metre deep sand filter, where sand of an effective grain size D_{10} = 0.24 mm and uniformity coefficient Cu = 3.3 was used, was able to remove 48% of the phosphorus from septic tank effluent. Consequently, a leaching bed or sand filter designed, as mentioned above, would be able to reduce the small quantities of phosphorus from the grey water septic tank effluent to an acceptable level.

b. Nitrogen Concentration and Removal of Nitrogen by Soil

Nitrogen is also a key nutrient that should be removed from wastewater because it contributes to eutrophication of surface water and because an excess of nitrogen in ground water can be a health hazard.

Nitrogen is present in food and particularly in proteins in relatively large quantities. The reported amount of nitrogen entering the toilet septic tank with human excreta is about 15.3 g/p/d in the urine and about 1.0 g/p/d in the feces[16] ; about 90% of the nitrogen in raw municipal wastewater is in a form of ammonia or urea from which ammonia is derived[17].

The determined average concentrations of ammonia and total Kjeldahl nitrogen* in the toilet septic tank effluent were 138 mg/l and 153 mg/l respectively (Table 2). The ammonia nitrogen in the toilet septic tank effluent amounts to 90% of the total Kjeldahl nitrogen. The concentrations of nitrite and nitrate in the septic tank effluent were 0.02 and 0.22 mg/l respectively. The total output of nitrogen from the toilet (black) water septic tank was about 18 g/p/d.

As anticipated, the concentration of nitrogen in the grey water septic tank was very low, 1.7 mg/l of ammonia in 11.3 mg/l of total Kjeldahl nitrogen were observed. The concentrations of the nitrites and nitrates in the grey water were of the same order of magnitude as in the effluent from the toilet septic tank (Table 2).

The low amount of nitrogen in the grey water septic tank effluent is subjected to further reduction during the transformation of the nitrogen while moving through soil to the ground and surface waters. In the upper layers of the soil, where enough oxygen is available, the ammonia is oxidized to nitrate. In the deeper zones of the soil, where less oxygen is available, the denitrifying bacteria in the soil contribute to denitrification of the nitrate to nitrogen gas and nitrous oxide. Most of the nitrogen from the nitrate is released as N_2 causing some loss

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* Total Kjeldahl nitrogen includes ammonia and organic nitrogen but does not include nitrite and nitrate nitrogen.

of nitrogen. According to Lance[18], 10 to 15% of the nitrogen is lost when sewage is applied to soil. Soil moisture, which saturates some large soil pores, regulates the presence of oxygen and, consequently, the nitrification and denitrification processes. Plants also stimulate denitrification[19]. Bradbend and Clark[20] estimated that the total losses from denitrification amount to 10 - 30% of the nitrogen applied to soil in chemical fertilizers.

The total nitrogen content observed in the grey water septic tank effluent, including nitrites and nitrates was 11.5 mg/l (Table 2). If only 10% of the nitrogen is lost, when travelling through a soil filter, the concentration of nitrogen in the effluent from the grey water tank, entering the ground and surface waters, will be close to the permissible 10.0 mg/l (as N) concentration of nitrogen in public surface water supplies[21].

c. Coliform Organisms Concentrations

Relatively high concentrations of fecal and total coliform organisms were observed in the grey water septic tank effluent. The average concentration of fecal coliform organisms was as high as 1.4×10^6 per 100 ml (Table 2). The range of magnitude of the fecal concentration was the same as usually observed in effluents from domestic wastewater septic tanks where all the domestic wastewater is treated. The detention time in such tanks is usually 2 to 3 days. A concentration of 1.01×10^6 of fecal coliform organisms per 100 ml was observed by Viraraghavan and Warnock[22] in effluent from a septic tank at a rural household in Quebec and a concentration of 1.08×10^6 per 100 ml was observed by Brandes[11] in effluent from a septic tank at the Orillia Hospital house. The fecal coliform organisms concentration observed in the effluent from the black water septic tank, of the same house where

the grey water tank is located, was relatively low (0.04×10^6 per 100 ml) due probably to the fact that only toilet wastewater was treated in that tank and because of the unusual long detention time of the toilet wastewater in that tank ($\sim$10 days).

In the previous chapter of this study, the chemical characteristics of the grey water septic tank effluent were compared with characteristics of the effluent from the black (toilet) water septic tank of the same house. It seems, however, unjustifiable to compare the concentrations of fecal coliform organisms in the effluent from the grey water septic tank, in which kitchen and bath wastewater was treated and in which the detention time was about three days, with the concentrations of fecal coliform organisms in the effluent from the black (toilet) septic tank in which the detention time was about ten days. The bacterial growth in the septic tank depends clearly on the raw wastewater composition and on the detention time.

The average concentration of total coliform organisms observed in the grey water septic tank effluent, of this study, was higher than in normal domestic septic tanks. (Table 2). It was as high as 24×10^6 per 100 ml whereas in normal septic tanks the concentrations of total coliform organisms were 5.63×10^6 per 100 ml as reported by Viraraghavan and Warnock[22] and 2.6×10^6 per 100 ml as reported by Brandes[11].

It was of interest to compare the high coliform counts observed in grey water, with observations made by other authors in similar grey water studies.

In an unpublished report by Pancuska et al of the Ontario Research Foundation[23] the authors, as a result of their assessment of grey water of a Great Lakes cargo carrier, reported concentrations of fecal coliform organisms from less than 10/100 ml to 2×10^8/100 ml

in the shower wastewater and from less than 10/100 ml to 4 x 10^6/100 ml in the galley waste. In a second report by the ORF, Smith et al[24] confirmed the high concentrations of the fecal coliform organisms in the shower and galley wastewater reported previously by Pancuska et al.

In a similar Swedish study by Olsson et al[6] the concentration of total and fecal coliform organisms in grey water from kitchens and bath combined were 3.6 x 10^6/100 ml and 0.88 x 10^6/100 ml respectively, (Table 2). Hypes et al[8] observed concentrations between 3.77 x 10^7 to 11.1 x 10^7 of "possible" coliform organisms per 100 ml of bath water samples collected from a tank 24 hours after completing the bath. The authors stress, however, that their counts were "approximately 1 to 2 orders of magnitude greater than results obtained using standard coliform count procedure[8]".

The reason for observed high concentrations of coliform organisms in grey water and particularly those of fecal coliform organisms was not completely clear.

Generally, the presence of fecal coliform organisms in wastewater is used as an indicator of its contamination with human (or warm-blooded animal) fecal wastes and of possible enteropathogenic microorganisms contained therein. However, cases are reported in literature[25,26] where high densities of fecal coliform organisms observed in polluted waters were due to certain biotypes of the genus Klebsiella associated mostly with upper respiratory tract and hospital-acquired infections. Klebsiella can multiply in waters contaminated with wastes from wood pulping processes[25,26] or textile finishing plant effluents[27] not evidently contaminated with sewage pollution. In laboratory tests, Klebsiella meet the criteria for fecal coliforms. Suggestions were also found in literature[28] that in waters containing large amounts of organic matter,

E. coli, considered as a representative of fecal coliform organisms, grows abundantly even in the absence of sewage or bathing pollution.

In order to find out whether the microorganisms do grow in the grey water septic tank, or they enter the tank in high concentrations from the kitchen sink and bath tub, three composite samples were taken directly from the pipes connecting the kitchen sink and the bath tub with the grey water septic tank (Figure 2). The samples were taken at approximately biweekly time intervals.

As seen in Figure 2, the wastewater from the kitchen sink and bath tub was running through the sampling bottles, during the time intervals between sampling and thus the composite samples were considered as representative. The wastewater samples taken from the pipes were tested for concentrations of total and fecal coliform organisms. Additionally, precise taxonomic identifications of the fecal coliforms were accomplished by the Microbiology Section of the Laboratory Services Branch of the Ministry in order to determine which specific types made up the high concentrations of the fecal coliforms in the grey water.

Table 3 shows the average concentrations of the total and fecal coliform organisms in the wastewater from kitchen and bath combined, from the kitchen only and from the grey water septic tank.

TABLE 3 Bacteriological Characteristics of Grey Water Samples

	Kitchen & Bath Combined	Kitchen Only	Grey Water Septic Tank
Total Coliform Organisms per 100 ml	117×10^6	75×10^6	24×10^6
Fecal Coliform Organisms per 100 ml	13×10^6	0.9×10^6	1.4×10^6

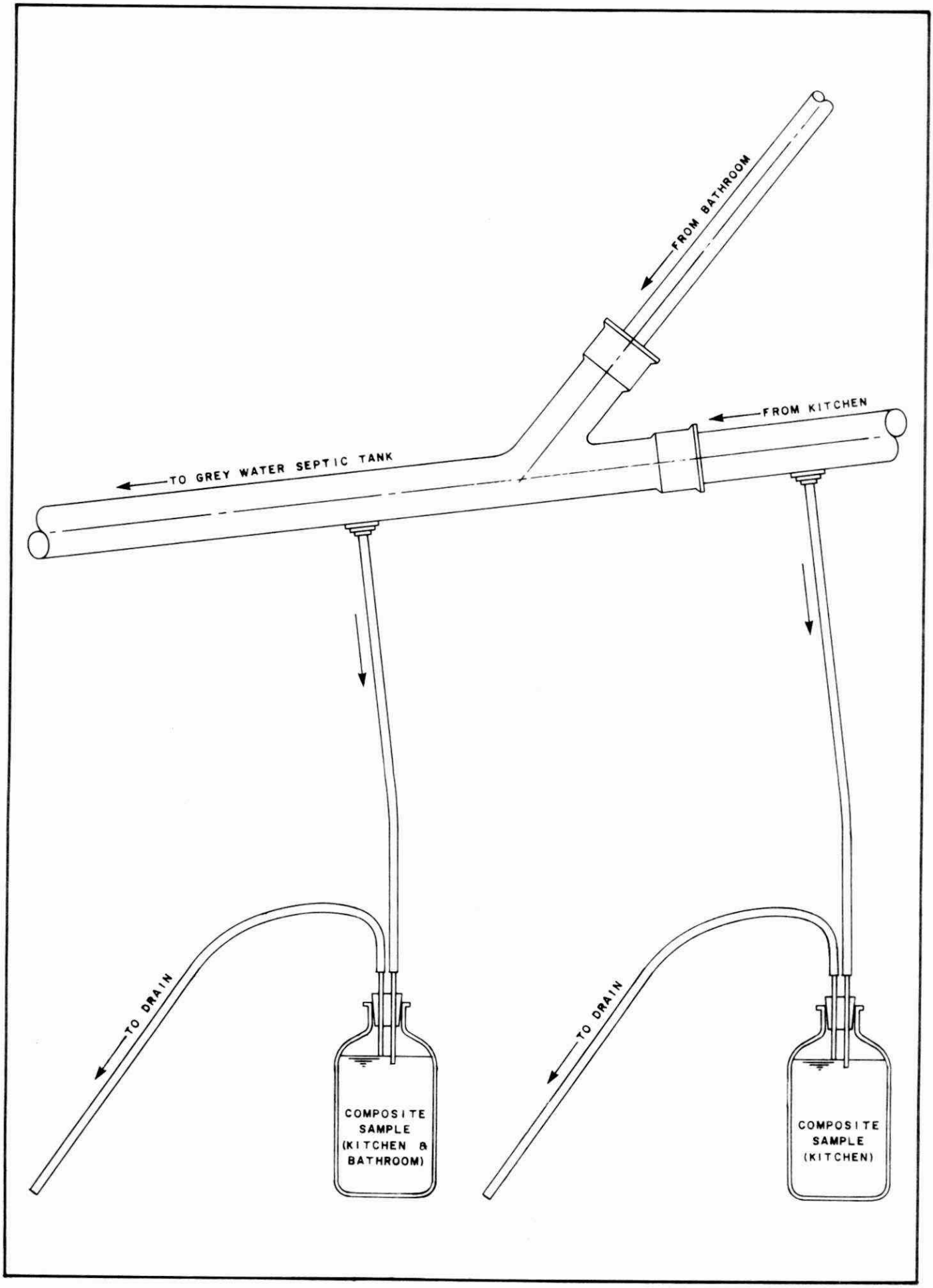

FIGURE 2 - SAMPLING OF KITCHEN AND BATHROOM WASTEWATERS (IN BASEMENT OF HOUSE)

The concentrations of coliform organisms in the composite samples from the pipes appeared to be within the range of concentrations observed in the grey water septic tank effluent (Table 2). The reason for such high concentrations, is the ability of the total and fecal coliform organism to grow abundantly in the sampling bottles installed in the basement where the temperature was about 20°C. Supposedly, a similar growth could also take place inside the pipes.

A grab sample taken from the pipe connecting the kitchen sink with the grey water septic tank (Figure 2) showed, after two hours, concentrations of 7.5×10^6/100 ml of total coliform organisms and 0.53×10^6/100 ml of fecal coliform organisms. The sample was kept in the laboratory at a temperature of 20°C for 12 days and tested every 2-4 days for concentrations of total and fecal coliform organisms. Results are presented in Figure 3. As seen, a maximum concentration of coliform organisms was observed during the time interval between the 24th and 96th hour after the sample was taken. The maximum concentrations observed were: 119×10^6/100 ml of total coliform organisms and 5.1×10^6/100 ml of fecal coliform organisms. After that period a drop in concentrations of total and fecal coliform organisms was observed.

The results of the taxonomic identification have shown that all the fecal coliform isolates were Escherichia coli. In view of the generally accepted indicator status of this organism in environmental pollution a potential health hazard could possibly be assigned to grey water effluents, but its significance in this particular situations remains to be determined.

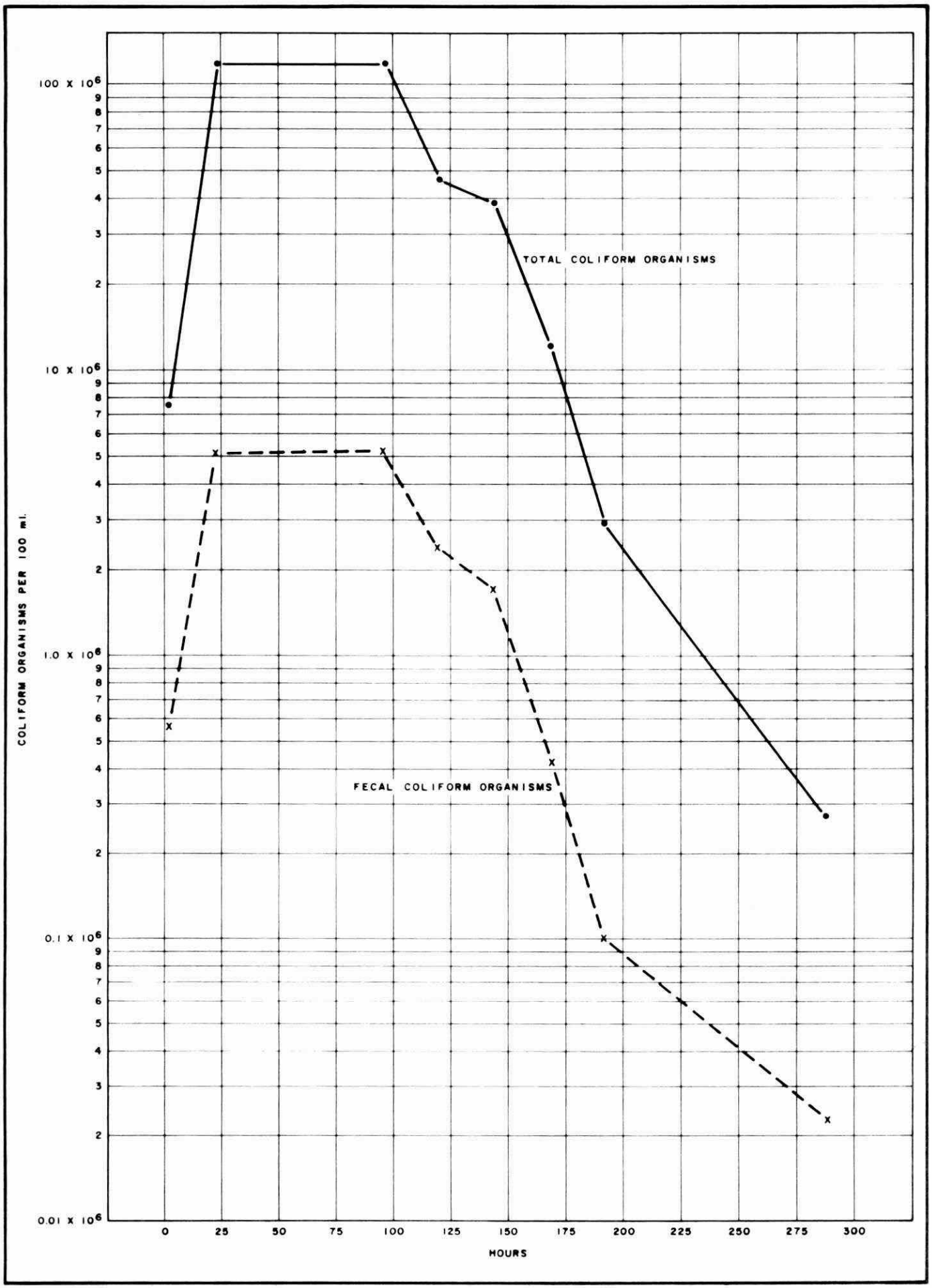

FIGURE 3 - MULTIPLICATION RATE OF COLIFORM ORGANISMS IN KITCHEN GREY WATER AT 20°C (SAMPLE FROM PIPE BENEATH KITCHEN SINK)

3.3 Quantities of Contaminants in the Effluents from Grey Water and Black (Toilet) Water Septic Tanks.

Table 4 presents the quantities of contaminants in grams per person per day (g/p/d) and in coliform organisms per person per day (.../p/d) in the effluents from the grey water and toilet (black) water septic tanks. The quantities were calculated from the determined average concentrations of the contaminants in the effluents (Table 2), from the determined water usage in the toilet and from estimated water usage in the kitchen and bathroom. Table 4 shows also the portions of contaminants in each of the septic tank effluents (in %) as related to the total quantities.

As seen from Table 4, the effluent from the grey water septic tank contains 8% of the total phosphorus quantities, 48% of the total solids, 69% of the suspended solids, 7% of the total Kjeldahl nitrogen and 1.2% of the ammonia entering the leaching beds from both of the septic tanks. The quantities of BOD_5, TOC and COD (in g/p/d) in the effluents of both of the septic tanks were almost equal. Ninety-nine percent of the total coliform organisms and 97% of the fecal coliform organisms entered the leaching beds from the grey water septic tank.

The quantities of contaminants in the effluents from the septic tanks, which are expressed in grams per person per day or in coliform organisms per person per day, do not represent the direct contribution of contaminants by the residents of the house. Some of the contaminants and particularly the microorganisms are subjected to chemical and biological transformation during the time they are detained in the pipes and in the septic tanks.

The average quantities of the total and fecal coliform organisms leaving the grey water septic tank were 30.2×10^9 and 1.8×10^9/p/d

TABLE 4 QUANTITIES OF CONTAMINANTS (Per Person Per Day) IN EFFLUENTS FROM GREY WATER AND BLACK (TOILET) WATER SEPTIC TANKS*

	THIS STUDY				REPORT BY OLSSON et al (6)			
	Grey Water**	Black Water	% Division		Grey Water**	Black Water	% Division	
			Grey	Black			Grey	Black
Total Phosphorus (as P)	0.2	2.2	8	92	0.9	1.6	36	64
Soluble Phosphorus (as P)	0.02	1.79	1	99	0.02	~0.01	65	35
Total Solids	66.5	73.3	48	52	58	53	52	48
Suspended Solids	20.4	9.1	69	31	16	30	35	65
BOD_5	18.8	11.0	63	37	22	20	52	48
TOC	15.8	11.5	58	42	-	-	-	-
COD	46.1	30.5	60	40	-	-	-	-
Ammonia (as N)	0.2	16.28	1.2	98.8	-	-	0.07	-
Total Kjeldahl (as N)	1.4	18.05	7	93	0.9	11	8	92
Total Coliform Organisms	30.2×10^9	0.3×10^9	99	1	12.9×10^9	4.8×10^9	73	27
Fecal, Coliform Organisms	1.8×10^9	0.05×10^9	97	3	2.5×10^9	3.8×10^9	40	60

* All quantities are in g/p/d except of coliform organisms which are in numbers/p.d.

** The grey water contains kitchen and bathroom wastewater only. Phosphorus free detergents were used in the house under this study, phosphorous detergents were used in the houses studied by Olsson et al.

respectively; in the black water septic tank effluent the quantities were 0.3×10^9 and 0.05×10^9/p/d respectively. However, as mentioned before, the concentrations of the coliform organisms in the black water septic tank effluent were unusually low and a comparison of the grey water bacterial quantities with those in the black water septic tank seems to be unfounded. Table 5 shows the quantities of coliform organisms leaving the grey water septic tank as compared with a normal household septic tank of almost the same detention time.

TABLE 5 QUANTITIES OF COLIFORM ORGANISMS IN EFFLUENT FROM GREY WATER SEPTIC TANK AND NORMAL* HOUSEHOLD WASTEWATER

	Detention Time days	Water Flow l/p/d	Coliform Org. Concentrations Total/ 100 ml	Fecal/ 100 ml	Coliform Org. Quantities Total per p/d	Fecal per p/d
Grey Water (This study)	3.0	126.0	24.0×10^6	1.4×10^6	30.2×10^9	1.8×10^9
Household Wastewater (Orillia study Ref. 11)	2.4	177.4	2.6×10^6	1.1×10^6	4.6×10^9	2.0×10^9

The quantities of the total coliform organisms appeared to be about seven times higher in the grey water septic tank effluent. The quantities of the fecal coliform organisms were almost the same in both of the effluents.

The high bacterial quantities (in numbers per person per day) in the grey water septic tank were probably due to the fact that kitchen wastewater contains large amounts of organic matter which has

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* By "normal" is meant a septic tank for household wastewater treatment of a detention time between 2 and 3 days as recommended by regulations[12]

undergone little breakdown whereas toilet wastewater contains only material which has undergone considerable microbial and enzymatic breakdown during its passage through the human digestive tract. It seems reasonable to suppose that toilet (black) wastewater may then be less degradable and support a lower bacterial population than the kitchen wastewater during digestion.

The same assumption is also applicable to the observed low concentrations of coliform organisms in the black (toilet) wastewater septic tank as compared to concentrations in a regular domestic septic tank where kitchen wastewater is also treated.

In a similar study by Olsson et al[6], the quantities of total and fecal coliform organisms in the grey water were 12.9×10^9 and 2.5×10^9/p/d respectively (Table 4). The quantities of the coliform organisms observed, by the authors[6], in the black (toilet) wastewater were of the same order as in the grey water.

3.4 Removal of Coliform Organisms by Soil Filters

Leaching beds and sand filters provide strong adsorptive removal of bacteria. Ziebel et al[29] in their studies on the fecal and total coliform organisms removal ability of an absorption field in sandy soil, have shown that the concentration of fecal coliform organisms in soil dropped from a concentration of 4.0×10^6 per 100 grams of soil at the base of the leaching bed trench, to less than 200 bacteria per 100 grams of soil in a distance of 30 cm below the base. A 99.5% removal of coliform bacteria was achieved. Similarly, the concentration of the total coliform organisms dropped, at the same depth from 23.0×10^6 per 100 grams of soil to less than 600 per 100 grams of soil; the removal was 99.7%. The authors showed also that a sand filter of an effective grain size D_{10} = 0.45 mm and uniformity coefficient

Cu = 3.9 was able to reduce the fecal coliform organisms concentration from 230,000 per 100 ml of effluent to 4,200 per 100 ml (81.7% removal). The concentration of total coliform organisms was reduced from 2.4×10^6 per 100 ml to 0.13×10^6 per 100 ml. (94.6% removal) at the same time.

Brandes et al[15] in their study on removal of pollutants from domestic sewage by underdrained soil filters have shown that a 1.0 meter deep sand filter of an effective grain size D_{10} = 0.24 mm and uniformity coefficient Cu = 3.9 was able to reduce the concentration of fecal coliform organisms from 2.0×10^6 per 100 ml in the septic tank effluent to 0.03×10^6 per 100 ml in the effluent from the sand filter. (98.5% removal). The concentration of the total coliform organisms dropped at the same time from 19.9×10^6 per 100 ml to 2.3×10^6 per 100 ml. (88.4% removal). When using a sand filter of the same sand characteristics and applying a smaller hydraulic load (7.0 $1/m^2$ day)* Brandes[30] achieved almost a complete removal of total and fecal coliform organisms from household wastewater. Less than 500/100 ml of total coliform organisms and less than 30/100 ml of fecal coliform organisms were observed in the final effluent from a sand filter.

As seen from the above studies[15,29,30] the extent of coliform organisms removal by soil filters varies from 81.7 to ∿100%. When only the minimum bacteria removal is achieved, additional filtration or disinfection of the final effluent would be required before being discharged into ground or surface waters. The permissible concentration of total and fecal coliform organisms in public water supplies are 5000/100 ml and 500/100 ml respectively[21].

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* 1 $1/m^2$ = 1 mm = 0.02 Imp. gal/sq. ft.

3.5 Concentration of Contaminants in Sludges From Grey and Black (Toilet) Water Septic Tanks

As mentioned, the accumulation rate of the sludge in the grey water septic tank was extremely low. Only one sludge sample was taken (on June 2, 1976) from the grey water tank after a 43 month period of the septic tank operation. The grey water septic tank was then pumped out and regular sampling started, however, because of the very low sludge accumulation rate, it was not possible to obtain large sludge samples from the grey water septic tank during the nine month period of this study.

The concentrations of contaminants in the sludges from the grey and black water septic tanks are presented in Table 6. The total and soluble phosphorus concentrations in the sludge from the grey water septic tank were 12.0 and 1.0 mg/1 respectively; the phosphorus concentrations in the black water sludge were 610 and 1.7 mg/1 respectively. Similarly, much less total Kjeldahl nitrogen was observed in the sludge from the grey water (150 mg/1) than in the sludge from black water (2200 mg/1). Twenty-three percent of the nitrogen in the grey water sludge was in a form of ammonia, while the portion of ammonia in the black water sludge was less than 1%.

The total solids concentrations in the sludges from the grey and black water tanks were 2820 and 23350 mg/1 respectively and the BOD_5 concentrations were 2300 and 6000 mg/1 respectively. The concentration of the total coliform organisms in the grey water sludge was about nine times higher than in the black water sludge, however, the fecal coliform organisms concentration was lower in the sludge from the grey water tank.

TABLE 6

CONCENTRATION OF CONTAMINANTS IN SLUDGES FROM GREY AND BLACK (TOILET) WATER SEPTIC TANKS*

	CONTAMINANTS IN SLUDGE	
	Grey Water S.T.	Black Water S.T.
Total Phosphorus (as P)	12.0	610
Soluble Phosphorus (as P)	1.0	1.7
Total Solids	2820	23350
BOD_5	2300	6000
TOC	1270	NT**
COD	8640	NT
pH	6.5	NT
Ammonia (as N)	35.0	19.0
Total Kjeldahl N (as N)	150.0	2200
Nitrite (as N)	0.01	0.01
Nitrate (as N)	0.2	0.98
Chlorides (as Cl)	88	50
Sulfates (as SO_4)	5.0	28
Aluminum (as Al)	1.6	5.3
Iron (as Fe)	30	160
Calcium (as Ca)	NT	66
Magnesium (as Mg)	NT	10
Sodium (as Na)	80	55
Potassium (as K)	13	22
Alkalinity (as $CaCO_3$)	276	NT
El. conductivity (μmho/cm)	840	NT
Total Coliform Organisms	8.2×10^6	0.9×10^6
Fecal Coliform Organisms	0.02×10^6	0.9×10^6

* All data are in mg/l except of coliform organisms concentrations which are in numbers per 100 ml.

** NT - Not Tested

4. CONCLUSIONS

Studies on two separate septic tanks used by the same house for treatment of grey water from the kitchen and bathroom and for treatment of black water from the toilet have led to the following conclusions:

1. The use of a separate grey water septic tank for treatment of kitchen and bathroom wastewaters has extended the detention time in the toilet septic tank.

2. The use of phosphorus-free detergents in the house caused a reduction in the average concentration of total and soluble phosphorus in the grey water septic tank effluent to 1.4 mg/l and 0.17 mg/l respectively. In a similar (Swedish) study, where normal phosphorus containing detergents were used, the respective average concentrations of the total and soluble phosphorus in the grey water were: 7.8 and 0.24 mg/l.

   The average concentrations of the total and soluble phosphorus in the black water septic tank effluent of this study were 18.6 and 15.2 mg/l respectively.

3. About 88% of the phosphorus in the grey water septic tank effluent was in a nonsoluble form. Only 18% was the nonsoluble portion of the phosphorus in the effluent from the black water septic tank.

4. The average total Kjeldahl nitrogen concentration in the grey water septic tank effluent was 11.3 mg/l, i.e. about 14 times lower than in the effluent from the black (toilet) water septic tank.

   About 15% of the nitrogen in the grey water septic tank effluent was in a form of ammonia while the portion of ammonia in the nitrogen of the black water septic tank effluent was 90%.

5. The average concentrations of total and suspended solids, BOD_5, TOC and COD in the effluents from the grey water and black (toilet) water septic tanks were of the same order of magnitude.

6. The average concentrations of the total and fecal coliform organisms in the grey water septic tank effluent were: 24×10^6 and 1.4×10^6/100 ml respectively. The respective concentrations of the total and fecal coliform organisms in the black (toilet) water septic tank effluent were: 0.25×10^6 and 0.04×10^6/100 ml. High concentrations of coliform organisms observed in the grey water septic tank effluent are attributed to the fact that kitchen wastewater contains large amounts of organic matter which has undergone little breakdown whereas toilet wastewater contains only material which has undergone considerable microbial and enzymatic breakdown during its passage through the human digestive tract. The toilet wastewater may then be less degradable and support a lower bacterial population than the kitchen wastewater during digestion.

7. All fecal coliform organisms in the grey water were identified as Escherichia coli.

8. The average quantity of fecal coliform organisms in the effluent from the grey water septic tank was 1.8×10^9/p/d i.e. approximately the same as in effluents from normal domestic septic tanks (2.0×10^9/p/d). The quantity of the total coliform organisms in the grey water septic tank effluent was 30.2×10^9/p/d or about seven times higher than in normal tanks.

9. The quantities of phosphorus and nitrogen leaving the grey water septic tank were relatively small. They were 0.2 and 1.4 grams/p/d respectively. The respective quantities of phosphorus and nitrogen

leaving the black water septic tank were 2.2 and 16.3 g/p/d.

10. The observed sludge accumulation rate in the grey water septic tank was about 8.3 litres/p/y. The sludge accumulation rate in the black (toilet) septic tank was 65.7 litres/p/y.

11. The required time intervals between grey water septic tank cleanings are about 8 to 10 times longer than the respective time intervals recommended for normal household septic tanks.

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